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Self-control performance enhances self-control performance at similar tasks

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RUNNING HEAD: Self-Control Enhancement

Getting into it.

Self-Control Performance Enhances Self-Control Performance at Similar Tasks.

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Abstract

In this paper we claim that the well-established reduction in self-control performance following prior exertion of self-control (the so-called ego depletion effect) is a consequence of people's adaptation to situational demands. Consistent with this claim that follows from cognitive control theory, we show that (1) self-control performance improves during tasks that are typically used as resource depletion tasks and that (2) typical depletion effects occur only when the nature of the response conflicts in the two subsequent tasks is different. When the nature of the response conflicts in the two subsequent tasks is similar, we found that exerting self-control improves subsequent self-control performance. Implications for the self-control strength model are drawn and avenues for future research are sketched.

Keywords: self-control, ego depletion, cognitive control

The self-control strength model (Muraven & Baumeister, 2000) states that exerting self-control taxes a limited resource that is akin to energy or strength, and thus brings people in a state of resource depletion. This state reduces people's capacity to exert self-control in the next phase. There is wide agreement that a state of depletion is undesirable (Vohs & Baumeister, 2004). It reduces people's capacity to engage in activities that are highly valued, such as intellectual performance (Schmeichel, Vohs, & Baumeister, 2003), food intake control (Vohs & Heatherton, 2000), and rational decision making (Bruyneel, Dewitte, Vohs, & Warlop, 2006). In this paper, we challenge this grim view on the depletion state, and claim that depletion is a consequence of an adaptive strategy that helps people to cope with a demanding task. As such, we hope to gain more insight in the processes underlying self-control depletion.

In the past decade, tens of studies have documented the so-called depletion effect (for a review, see Vohs & Baumeister, 2004). These studies typically comprise two phases. In a first phase, half of the people face a situation that requires them to exert self-control and half do not. In the second phase, people are put in another situation that requires them to exert self-control (e.g. Baumeister, Bratslavsky, Muraven, & Tice, 1998). The robust finding is that self-control performance suffers in the second phase for those people who exerted self-control in the first phase relative to those who did not exert self-control in the first phase. Taken together, these studies yield an impressive set of behaviors that appear to rely on the scarce resource that is needed in self-control. Previous research has shown that responses such as thought control (Muraven, Tice, & Baumeister 1998), emotional regulation (Baumeister et al., 1998), response inhibition (Wallace & Baumeister, 2002), repeated choosing (Bruyneel et al., 2006), intellectual performance (Schmeichel et al., 2003), food intake control (Vohs & Heatherton, 2000), rational consumer behavior (Vohs & Faber, 2006), self-presentation

(Vohs, Baumeister, & Ciarocco, 2005), and suppressing stereotype-consistent behavior (Vohs et al., 2005) involve the scarce self-control resource.

Although the basic finding is undisputed, the nature of the scarce mental resource has remained elusive. Several moderators have been proposed that shed some light on it. Martijn et al.'s (2003) findings that making people think that an actually depleting task is not depleting reverses the depletion effect, suggests that resource depletion effects partially rely on the belief that exertion deserves rest. Similarly, Muraven and Slessareva (2003) showed that depletion occurs only in circumstances of low motivation. Webb and Sheeran (2003) found that making well-designed plans (implementation intentions) removes the detrimental depletion effects. Others have proposed mediators that increase our understanding of the nature of the scarce mental resource. For example, Vohs and Schmeichel (2003) showed that subjective time perception slows down in a state of depletion, and they provided evidence that this distorted time experience statistically mediated the typical depletion effects.

In this paper, we propose that depletion effects result from an individual's attempts to adapt to a situation that involves a response conflict. Adapting to a certain response conflict increases the fit between the individual's response set and the demands of that particular situation but decreases the fit between the individual's response set and the demands of a new situation triggering a different response conflict. The implication of our interpretation of the depletion effect in terms of adaptation to a response conflict is that the typical depletion effect should *reverse* if the response conflict in both situations is similar. The contribution of this paper is twofold. The empirical contribution of this paper is showing that the depletion effect critically depends on the dissimilarity of the response conflict in phase 1 and phase 2. We predict that depletion effects will occur only in case response conflicts are dissimilar in the two consecutive phases, and will *reverse* in case response conflicts are similar in the two

consecutive phases. The theoretical contribution consists of providing insight in the nature of depletion.

The remainder of this paper is organized as follows. We first briefly review the cognitive control and self-control strength theories about how people deal with response conflicts. Then we clarify how the cognitive control theory can explain typical depletion effects and why it predicts performance *improvements* for consecutive self-control tasks involving similar response conflicts. After subsequently testing the central prediction in three studies, we conclude the paper with drawing theoretical implications from our results and sketching some future research opportunities.

Depletion results from adapting to response conflicts

Adapting to self-control situations involves a fine-tuning of one's response set to increase the fit with the situational demands (Miller & Cohen, 2001). For instance, adapting to a traditional Stroop task implies learning to ignore the feature that is dominant as a result of more extensive and consistent use (i.e., the word meaning) and focusing on the feature that is subdominant as a result of less extensive and consistent use (i.e., the word color). In the first trials, the response conflict is intense: the response that wins the race is the wrong one. As the individual learns to ignore the dominant but irrelevant dimension, the response conflict weakens and performance improves.

Cognitive control refers to the remarkable ability of the cognitive system to perform well at specific tasks through adjustments in perceptual selection, response biasing, and the on-line maintenance of contextual information. Cognitive control theory (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; Miller & Cohen, 2001) claims that people have a system that monitors for response conflicts. This system induces control processes to become actively

involved in potentially challenging situations. According to the theory, the actual attempt to perform a difficult task leads to the recruitment of cognitive resources through the detection of conflict. Conflict indicates that current levels of control are insufficient to meet task demands, and thus signals a demand for greater control. The detection of conflict is an important function of a particular area of the human frontal lobe, namely, the anterior cingulate cortex (ACC).

Once the ACC is activated, the prefrontal cortex (PFC) guides task performance and increases the likelihood that the desirable response (e.g., 'green') instead of the dominant response (e.g., 'red') is emitted upon the appearance of the appropriate cue (e.g., the word red written in green). Thus, the PFC is important when top-down processing is needed, such as when mappings between sensory inputs, thoughts, and actions are weakly established relative to other existing ones. Patterns of activity in the PFC configure processing in other parts of the brain in accordance with current task demands. Control is adjusted on-line, in response to variations in performance.

The assumption that conflict monitoring serves as a basis for the regulation of control enables us to explain some interesting empirical phenomena involving on-line shifts in control (Botvinick et al., 2001; Miller & Cohen, 2001). The most studied example of task-induced adjustments in control is the classic Stroop conflict paradigm (Stroop, 1935). Stroop tasks require people to name the color in which a color word is displayed. Response times are greater if there is a mismatch between the word color and the word meaning (e.g., the word 'RED' displayed in green) than if the two are matched (e.g., the word 'RED' displayed in red). Incongruent trials are difficult because word reading, a strongly automatic but task-inappropriate process, interferes with color naming. A Stroop task thus involves conflict between processing pathways leading to correct (but otherwise weaker) and incorrect (but very strong) responses. One of the most fundamental aspects of cognitive control and goal-

directed behavior in general is the ability to select this weaker, task-relevant response over the stronger, but task-irrelevant response (Miller & Cohen, 2001). Cognitive control theory claims that this ability relies on the detection of response conflict and the subsequent recruitment of control processes.

Consistent with the important role of conflict is the finding that the degree of interference from word reading on color naming depends on the frequency of incongruent trials, with less interference occurring when incongruent trials are frequent (e.g., Tzelgov, Henik, & Berger, 1992). The occurrence of incongruent trials leads people to selectively attend to one attribute and focus more effectively on the color-naming task, enhancing their ability to avoid interference from the word-reading response. This is because incongruent trials involve a lot of conflict, which triggers activity in the anterior cingulate cortex and hence in the prefrontal cortex (Botvinick et al., 2001).

However, the recruitment and deactivation of cognitive control is a gradual process that is characterized by a degree of inertia (Botvinick et al, 2001). We claim that the inertia in the cognitive control system can account for depletion effects. Miller and Cohen (2001) asserted that the PFC must maintain the rules of a task in the face of distracters and that this rule activation often extends beyond the eliciting event. Botvinick et al. (2001) incorporated inertia in their model simulating cognitive control, and showed that a substantial degree of inertia between consecutive trials is necessary to reproduce behavioral data. The inertia of cognitive control processes allows us to claim that cognitive control theory can accommodate depletion effects. Performance on a task involving a response conflict will deteriorate when it is preceded by a task involving a different response conflict. The sustained activity in the PFC reduces the flexibility of the PFC for a while.

The self-control strength model and the cognitive control model.

Task circumstances that have been identified as involving a high demand for control require planning, decision-making, troubleshooting, the overcoming of a strong habitual or emotional response, or resisting temptation. They might also be ill-learned or contain novel sequences of actions, or be technically difficult (Shallice & Burgess, 1993; Norman & Shallice, 1986). Interestingly, both the cognitive control theory (e.g., Botvinick et al., 2001) and the self-control strength theory (e.g., Vohs and Baumeister, 2004) refer to these very task characteristics when theorizing about cognitive control and self-control, respectively.

The previous sections showed that the vast number of depletion effects that have been reported in the literature (for an overview, see Vohs & Baumeister, 2004) concerned a sequence of two such tasks involving a high demand. We argue that the deterioration in self-control performance from task 1 to task 2 that is typically observed can be accommodated by both the self-control strength theory and the cognitive control theory. It is well-known that self-control strength theory claims that exerting self-control in phase 1 consumes a scarce resource, through which process people's capacity to exert self-control in phase 2 is reduced. The explanation according to the cognitive control model is slightly different. Exerting self-control in phase 1 gears the PFC towards one particular response set that matches the current tasks demands, and thereby looses flexibility to quickly adjust to the demands of the task in phase 2. So in the traditional depletion paradigm, in which two *different* self-control tasks follow each other, both models can explain the observed behavior: self-control performance deteriorates from phase 1 to phase 2. We use the term ego depletion to refer to this well-established phenomenon. However, when the models are exported to a new situation in which two subsequent self-control tasks involve *similar response conflicts*, they start to produce sharply diverging predictions.

Cognitive control predictions

ACC activation has been associated with tasks involving various types of conflict. For instance, tasks calling for the overriding of relative automatic but task-inappropriate responses involve conflict between processing pathways leading to correct (but usually weaker) and incorrect (but usually strong) responses. Tasks requiring choice among multiple possible responses result in conflict during the period between stimulus presentation and response delivery because multiple incompatible response pathways are activated. Likewise, tasks that lead to the commission of errors are associated with conflict due to interference between the pathways leading to correct and incorrect responses (Botvinick et al., 2001).

In all cases, the detection of conflict results in an adjustment of one's behavior in response to one's own performance. Difficulty in the task results in a temporarily more focused, conservative approach and thus an increase in task performance (Botvinick et al., 2001). This leads to the straightforward prediction that when two similar highly demanding tasks follow each other, performance will improve from the first phase to the next.

Self-control strength predictions

The self-control resource has been shown to underlie various types of behaviors, such as response inhibition (Baumeister et al., 1998, study 1), response exaggeration (Schmeichel, Demaree, Robinson, & Pu, 2006), thought suppression (Muraven et al., 1998), or repeated choosing (Bruyneel et al., 2006). In all cases, it has been suggested that performance on these tasks relies on a scarce resource. The consumption of this resource reduces people's ability to exert self-control in the next phase, even at unrelated self-control tasks. This leads to the straightforward prediction that when two similar highly demanding tasks follow each other, performance will deteriorate from the first phase to the next.

The current studies

The aim of the current studies is to test the predictions derived from the self-control strength model and the predictions derived from the cognitive control model against each other. In the first two studies, we investigated whether continuing to exert self-control in the same domain either gradually reduces performance (consistent with the self-control strength model) or enhances performance (consistent with the cognitive control model). To give both models a fair test, we used procedures that have been successfully used as depletion inductions, and measured the evolution of performance *within* that task in the first two studies. In the third and fourth study, we mimicked the two phase paradigm of the depletion literature, and tested the importance of the similarity of the response conflict in the two tasks. We investigated whether the similarity between the two subsequent tasks moderates the direction of the depletion effect. To test this we applied a response reversal task (e.g. Paus et al., 1993) in the second phase of Study 3. In the first phase of that study, participants engaged either in a control task, a similar response reversal task (high similarity condition), or a thought suppression task (low similarity condition). The self-control strength model predicts a deterioration of response reversal performance in the two depletion conditions in comparison with the control condition. The cognitive control model predicts a deterioration of response reversal performance in the low similarity condition and an improvement of response reversal performance in the high similarity condition, both compared to the control condition. In the fourth study, we attempted to replicate the role of similarity for another type of task, and ruled out the possible concern that the performance improvement in the previous studies is driven by mere exercising effects. Specifically, we asked participants to restrict their urge to consume sweets in a first phase, which is assumed to be depleting (Baumeister et al, 1998, Study 1), and afterwards invited them to partake in a taste test (in which we asked them

to eat, similar response conflict) or a word anagram (different response conflict). The self-control strength model predicts that self-control performance will deteriorate, independently of the task. The cognitive control model, in contrast, predicts that self-control performance will *improve* in the taste test but decrease in the anagram task.

Study 1

In this correlational study, we investigated the evolution of performance on a task that has often been used to induce depletion: thought suppression (e.g. Muraven et al, 1998). We took care to copy previous procedures as accurately as possible to make sure that our version would be depleting as well. Given the success of thought suppression as a depletion inducing task, the self-control strength model predicts that performance at this task should deteriorate during the task. More specifically, this model predicts that the time lags between two subsequent occurrences of the inhibited thought should decrease during the task. In other words, the occurrences of the forbidden thought should follow each other more rapidly towards the end of the task. In contrast, the cognitive control model predicts that participants will adapt to the task requirements and thus that performance should improve during the task. This implies that the time lags between two subsequent occurrences of the forbidden thought should increase during the task. More specifically, the occurrences of the forbidden thought should follow each other more slowly towards the end of the task.

Method

Participants

Two hundred and three students participated in exchange for an experimental fee. Eighty-two (40%) were men.

Procedure

Participants were asked to engage in a thought-listing task for five minutes. They were instructed to write down their thoughts on a sheet of paper and to avoid thinking about a white bear. When thinking of a white bear, participants had to click a button that was centrally displayed on the computer screen before them, and immediately change their thoughts and try very hard not to think of a white bear again. The time that had passed since the beginning of the thought-listing task was registered at each mouse click. Previous studies already established that trying not to think of a white bear for five minutes leads to a state of depletion (e.g., Muraven & Slessareva, 2003).

Results and discussion

To test whether performance at the thought suppression task changed during the task, we calculated the lags between the subsequent times at which participants indicated that they had thought of a white bear. Each button-click was numbered from 1 (i.e., position 1) to the total number of clicks for that participant (i.e., position N). Then we calculated the correlation between the position of the click and the lag since the previous click, or since the start of the task in case of the first click. We can include only those 119 participants (60%) who clicked at least three times (producing two lags) because correlations can only be calculated with two observations. Of the 84 participants for whom we do not have observations, 21 did not click, 31 clicked once, and 32 clicked twice, leaving 119 participants in the analyses.

For the 119 participants, we found an average correlation between position and lag of r = 0.44, which is significantly different from zero, $t(118) = 7.77$, $p < .0001$. The lags between the subsequent button-clicks increased with the number of clicks, suggesting that participants progressively improved their performance at suppressing their thoughts.

These data show that people have progressively less trouble inhibiting the thought of a white bear. Note that these findings underestimate the decay because the last difference (from the last occurrence of the thought until the end of the task) is omitted, although this is the longest interval by far for most participants. Although thought suppression has been shown to induce depletion (e.g. Muraven et al, 2003), our findings suggest that exerting control improves self-control performance on the current task. Although compelling, the reduced occurrence of the forbidden thoughts may follow from a natural decay of activation or from the fact that people become progressively more bored or oblivious of the instructions, rather than from the fact that people get gradually better at exerting control, as we propose. Study 2 tried to alleviate these concerns by including a control condition and using a self-control task that is not susceptible to these alternative explanations.

Study 2

In this experiment, we again investigated the evolution of self-control performance within one task that has been well-established as a depletion inducing task. We selected the Stroop task with two levels of control demand (e.g. Wallace & Baumeister, 2002). In the high demand condition, participants had to ignore the dominant dimension (words) and focus on the less dominant dimension (color) to follow experimental instructions. In addition, they had to reverse the application of this rule when certain conditions were met. In the low demand

condition, participants had to focus on the dominant response dimension (words) to follow experimental instructions. We looked at performance in terms of response latency.

Because the Stroop task has been shown to induce depletion in a reliable way, the self-control strength model predicts that performance should deteriorate during the task. This should be the case in the high demand condition to a larger extent than in the low demand condition (i.e., because the former one demands more control and hence is more depleting). The cognitive control model, in contrast, predicts that participants will cope with the task demands, resulting in an increasing speed with which they give the correct response. This acceleration should be stronger in the high demand condition than in the low demand condition because the need for adaptation is larger than in the high demand condition.

Method

Participants

Participants were 74 students (32 men) participating in exchange for a participation fee.

Procedure

Participants were asked to engage in a variation of the Stroop task and to indicate the ink color of 50 color names. Words and ink colors were either matched (e.g., RED in red ink; Low demand condition) or mismatched (e.g., RED in yellow ink; High demand condition). In addition, in the High demand condition, in case a word in blue ink appeared, which was the case in 25% of the trials, participants were instructed to indicate the word rather than the ink color. Previous studies already established that this highly demanding condition leads to a state of depletion (e.g., Wallace & Baumeister, 2002) in comparison with the low demanding condition.

Results and discussion

Three participants who did not follow instructions were removed. A repeated measures analysis on the time needed to respond correctly to the trials with the level of demand (High vs. Low) as between-subjects factor revealed an overall significant linear decrease in response time from the first to the last trial: $F(1,69) = 55.79$, $p < .0001$. More interestingly, the decrease in the High demand condition (trend: $F(1,34) = 46.9$, $p < .0001$) was more pronounced (interaction: $F(1,69) = 9.85$, $p < .003$) than in the Low demand condition (trend: $F(1,35) = 11.58$, $p < .002$) (see Figure 1).

These data show that performance increases (response latency decreases) during the task, although this type of task has been shown to be depleting (Wallace & Baumeister, 2002). The decrease is more pronounced in the High demand condition than in the Low demand condition. This pattern of data is consistent with the cognitive control model, and at odds with the self-control strength model.

*****Insert Figure 1 here******

Study 3

In the third study, we aimed at replicating the findings of Studies 1 and 2 using the dominant paradigm of the depletion literature. That paradigm comprises two consecutive self-control tasks. In this study, we explored the moderating role of similarity between the two phases on the depletion effect. We applied three levels of similarity: high, neutral, and low. Two conditions of the three used in this study match a straightforward depletion paradigm. In

one condition, participants first engage in a non-depleting task and then proceed with a depleting response reversal task (i.e., the Control condition). In one other condition, participants first engage in a depleting thought suppression task and then engage in the same response reversal task (i.e., the Low similarity condition). Both the cognitive control and the self-control strength model predict that performance at the response reversal task should be worse in the latter condition than in the former.

The third condition is the most informative condition. In that condition, participants engage in two subsequent, similar depleting response reversal tasks (i.e., the High similarity condition). The self-control strength model predicts a depletion effect akin to the one in the thought suppression condition. That is, participants become depleted because of the response reversal task that they engage in in the first phase, which should reduce their capacity to successfully perform in the subsequent response reversal task. The cognitive control model, in contrast, predicts performance to improve in the second response reversal task in comparison with the control condition, as participants should fine-tune to the task demands of the first response reversal task.

Method

Participants

Seventy-five students (30 men) participated in exchange for course credit. One participant did not follow instructions and was discarded from analysis.

Procedure

In the first phase, participants engaged in a control task (i.e., Control condition), a thought suppression task (i.e., Low similarity condition), or a response reversal task similar to the

response reversal task of the second phase (i.e., High similarity condition). In the second phase, all participants engaged in a response reversal task.

Control task. Participants were asked to watch a five-minute relaxing power-point presentation with landscape pictures.

Thought suppression task. Participants were asked to engage in the same thought-listing task as the one used in Study 1. Participants were asked to click a button on the screen each time they thought of the forbidden concept (i.e. a white bear). Time was registered at each mouse click.

Response reversal task. Participants were asked to match a string of characters to a shape. The string of characters consisted of two letters out of the set of A, B, and C that were shown on the first screen. The shape was either a circle or a square, which was shown on the second screen. For instance, participants had to click the circle when they had seen the letter strings "AB" or "BC", and click the square when they had seen the letter strings "AC" or "BA" on the previous screen. The task consisted of 20 trials of which five trials (i.e., 25% of the trials) required a response reversal. If a cross was shown between the two letters, participants had to click the non-matching shape. A similar task requiring people to consult multiple rules and monitor their decisions carefully has been used successfully as a depletion inducing task before (Baumeister et al., 1998, Study 4).

In the second phase of the study, participants in all conditions were asked to engage in a similar response reversal task. The matching rule used in the response reversal task came in two versions (i.e., there was also a version relying on character strings consisting of two letters out of the set of E, F, and G). Half of the participants received the ABC version and the

other half received the EFG version of the response reversal task. Participants in the High similarity condition received the version that they had not engaged in before. Performance at the second response reversal task was our dependent variable.

In all conditions, participants' mood was assessed by means of the Positive Affect Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). This was done to validate that mood states were not different depending on self-control condition, thus ruling out a possible alternative account for our findings.

Results

Because the latency of incorrect responses would be difficult to interpret, only correct responses were used in all the subsequent analyses (see Bargh, Chaiken, Govender, & Pratto, 1992; Fazio, 1990). In order to lessen the influence of outliers, latencies below 300ms and above 3000ms were set at these respective boundaries (e.g. Greenwald, McGhee, and Schwartz, 1998). We calculated interference by distracting latencies for the non-conflict trials from the latencies for the response reversal trials.

Interference was significantly affected by the prior task: $F(2,72) = 8.92$, $p < .0004$. Figure 3 shows that, consistent with the typical depletion effect, interference was high in the Low similarity condition ($M = 2.00$, SD = 0.77) compared to the Control condition ($M = 1.58$, SD = 0.73), $t(70)=2.10$, $p < .04$, and the High similarity condition ($M = 1.17$, SD = 0.57), $t(70)=4.22$, $p < .0001$. In the High similarity condition, interference was *lower* than in the Control condition $t(70)=2.10$, $p < .04$.

Insert figure 3 about here

In the High similarity condition, people engaged in the response reversal task twice (r = .49, $p < .02$). Consistent with the between subject analyses, we found that in the High similarity condition (n = 25), interference was lower in phase 2 (M = 1.17, SD = 0.57, see above) than in phase 1 (M = 1.54, SD = 0.91; $F(1,24) = 5.39$, $p < .03$).

The effect of the similarity condition on subsequent self-control performance cannot be explained by mood differences. Levels of positive (Control: M = 26.6, SD = 6.7; Low similarity: M = 27.3, SD = 7.1; High similarity: M = 28.8, SD = 6.2; F (1,62) = 0.7, $p > .5$) and negative affect (Control: M = 14.5, SD = 4.1; Low similarity: M = 16.0, SD = 6.8; High similarity: M = 13.3, SD = 3.2; F (1,62) = 1.7, p = .18) did not differ between similarity conditions. Moreover, adjusting for positive and negative affect as covariates did not change the pattern of results reported above, suggesting that mood does not mediate the effect of similarity on self-control.

Discussion

The pattern of interference in the High similarity condition is consistent with the predictions of the cognitive control model, and at odds with the self-control strength model. Although the response reversal task is depleting, which is validated by the finding that interference was higher in the Low similarity condition than in the Control condition, it does not impede self-control performance in a highly similar task. At the contrary, a between-subject and within-subject analysis showed that it enhances performance.

One may object that the performance improvement in the High similarity condition is primarily driven by exercising and that this may even hide the actual depletion effect. This would imply that exercising would account for the large effect (d = 1.24) between the High similarity and Low similarity conditions. In the final study, we aimed at ruling out that

explanation by reducing the literal similarity between both phases, while keeping the response conflict similarity intact.

Study 4

In this study, we aimed at replicating the pattern of results for a different set of self-control tasks. We also aimed at ruling out a possible explanation in terms of exercising by omitting the literal similarity between the two subsequent tasks, while keeping the response conflict similarity between the two phases intact. To obtain this, we kept the task in phase 1 constant and manipulated response conflict similarity between the self-control tasks in both phases by manipulating the nature of the task in the second phase.

In the first phase, participants were either tempted with attractive chocolates but asked not to eat any (e.g. Baumeister et al, 1998, Study 1), or were asked to engage in a non-demanding task. In the second phase, half of the participants were asked to engage in a difficult anagram in which we measured their persistence in seconds (Baumeister et al., 1998, study 3). Backed by almost a decade of consistent findings, the self-control strength model unequivocally predicts that persistence on the anagram task will reduce in the group that was previously tempted and had to exert self-control to resist their urge to take a sweet, as compared to the control group. The cognitive control model provides us with the same prediction. The other half of the participants was asked to engage in a taste test rather than to solve an anagram in the second phase of the study. Controlling food intake in a taste test of attractive sweets requires self-control (e.g. Baumeister et al, 1998, Study 1; Shiv and Fedorikhin, 1999; Vohs and Heatherton, 2000). It is important to stress that the response conflict that is evoked in a taste test (“I would like to eat, but I shouldn’t eat too much”) is highly similar to the response conflict in the first phase (“I would like to eat, but I can’t”). Nevertheless, any spill over from

phase 1 to phase 2 cannot be the result of exercising or a persistence of instruction effects, because the task and the task instructions differ substantially across the two phases. For one thing, in the first phase, we ask them *not to eat*, whereas in the second task, eating was absolutely required to complete the central task in a meaningful way.

The self-control strength model predicts that depleted participants will have more trouble controlling their food intake than the control group, whereas the cognitive control model predicts that the depleted group will perform *better* at the taste test. Performance reflects success at regulating food intake.

Method

Participants

One hundred and fifty-two female students participated in exchange for a participation fee or for course credit. They came to the lab in groups of 4 to 8 people. We used only women because gender has a major impact on food regulation which is not the main concern of the current study (e.g. Fishbach, Friedman, & Kruglanski, 2003).

Procedure

Temptation manipulation. In the High temptation condition, participants were given a knowledge task on entering the laboratory. Participants were told that the manufacturer of the chocolate candy brand 'Quality Street®' was interested in consumer knowledge of the association between candy flavors on the one hand and wrap colors and shapes on the other hand. Participants were asked to associate twelve pictures of the candies (of different colors and shapes) with the corresponding flavor of each candy (e.g. 'chocolate with strawberry cream'). In addition, a bowl filled with lots of these 'Quality Street' candies was present next

to them. They were told that the candies were placed there because the pictures were not always very clear. They were not allowed to eat any candy *during* the knowledge task, but were told that they were free to eat as many chocolates as they desired *after* the knowledge task. In this way, participants had to exert self-control in order to resist the candies during the knowledge task. Before participants had the opportunity to eat the 'Quality Street' candy after the completion of the knowledge task, the second phase started. During the first phase of the study, participants in the No temptation condition were asked to match ten colors with ten concepts (e.g. 'white' with 'snow and 'green' with 'grass').

The self-control task in the second phase was either similar or dissimilar to the self-control task in the first phase.

High similarity. In the highly similar self-control task, participants engaged in a taste test of a relatively unhealthy product. In line with prior research, we consider restricting consumption in taste tests of unhealthy products as an act of self-control (e.g. Fishbach et al., 2003; Tice, Bratslavsky, & Baumeister, 2001). Participants were given two bowls of the same volume, one with regular M&Ms® (400 grams), and the other with the 'new' crispy M&Ms (300 grams). They were told that they were participating in a comparative taste test of both types of M&Ms. The participants were allowed to eat as many of the M&Ms as they needed to evaluate the M&Ms on several dimensions (e.g. 'are they crunchy?', 'are they hard to resist?'). After the taste test, the bowls were removed, and the experimenter weighed how many M&Ms had been consumed.

Low similarity. The low similarity self-control task consisted of untangling an anagram (e.g. Baumeister et al., 1998). Participants received a difficult anagram on computer. They received 8 characters and had to form appropriate words of at least 7 letters. Only five words

were possible and a pretest showed that the majority of the people found none. The time spent solving the anagram (i.e. a persistence measure) was recorded.

A pretest in the same population (n = 46) showed that the temptation manipulation did not affect positive (No temptation; M = 29.7, SD = 6.2; High temptation; M = 29.0, SD = 6.8, F<1) and negative affect (No temptation; M = 12.9, SD = 3.9; High temptation; M = 13.2, SD = 4.1, F<1). We preferred measuring affect in a different sample to preclude participants from consuming the candies of the first phase during the completion of the affect measure.

Results and discussion

Because the distributions of time spent and quantity consumed were skewed to the right, both variables were log-transformed. Both dependent measures were standardized. For the sake of clarity, the quantity consumed was reversed such that higher values mean better self-control for both self-control tasks. Figure 3 shows the interaction between Similarity and Temptation: $F(1,149) = 10.07$, $p < .002$. The main effects were not significant (Fs < 0.1). In the Low similarity condition, tempted people spent less time solving anagrams, $F(1,149) = 4.98$, $p < .03$ (tempted: M = 140s, SD = 136, not tempted: M = 189s, SD = 140). In the High similarity condition, tempted people performed better at the taste test by consuming less, $F(1,149) = 5.10$, $p < .03$ (tempted: M = 9.28g, SD = 5.9; not tempted: M = 13.12g, SD = 7.84).

*******Insert Figure 3 here*******

Study 4 replicates the finding of the previous studies that previous exertion of self-control enhances performance at a second self-control task provided that the second task is similar to the first task with respect to the response conflict it triggers. At first sight, these findings seem inconsistent with earlier findings showing that exerting self-control in a food temptation situation leads to *increased* consumption in a subsequent food consumption situation (Vohs & Heatherton, 2000, Study 1). However, at least for non-dieters in that study, the trend was consistent with our findings. In the "don't touch" condition, putting tempting food at non-dieters' reach reduced their consumption compared to putting tempting food out of reach.

General discussion

This paper compared two possible theoretical interpretations of the robust ego depletion effect (Vohs & Baumeister, 2004). The first interpretation, which is derived from self-control strength theory (Muraven & Baumeister, 2000), states that ego depletion reflects a reduction in strength, which is needed in the process of overriding one's behavior, thoughts, or emotions. The second interpretation, which is derived from cognitive control theory (Botvinick et al., 2001), states that ego depletion reflects an individual's temporal adaptation to highly demanding situations. Although indistinguishable in situations where two *unrelated* self-control tasks follow each other (i.e., both models predict a reduction in self-control performance), the two models yield sharply divergent predictions when applied to a situation in which two *similar* self-control tasks follow each other. The self-control strength model predicts that exerting self-control is depleting, and hence negatively affects self-control ability in any subsequent situation, irrespective of the similarity between both types of demand. The cognitive control theory, in contrast, predicts that response conflicts lead people to temporally

adapt to this type of situation, which should enhance their ability to deal with a subsequent similar response conflict.

Our data provide strong support for the cognitive control model. In Studies 1 and 2, we found that performance on tasks that are typically used as a depletion manipulation improves with time, although we know from previous research that participants are depleted by the end of the task. In Study 3, we used the two phase paradigm of the depletion literature, and found that a depleting response reversal task *enhanced* self-control performance on a similar task in the second phase. In Study 4, we showed that a state of depletion that was caused by inhibiting food intake subsequently improved self-control performance in the domain of food intake control.

Theoretical Implications

The first implication of our findings is that the ego depletion effect is moderated by the similarity of the response conflict in the two subsequent self-control demanding situations. Thereby, similarity is added to the short list of boundary conditions to the ego depletion effect, in addition to activated beliefs (Martijn et al., 2003), the construction of implementation intentions (Webb and Sheeran, 2003), and high levels of motivation (Muraven and Slessareva, 2003). The ego depletion effect occurs only when the response conflict characterizing two subsequent self-control phases is sufficiently different.

Similarity in response conflict does more than suppressing the depletion effect, however. Our findings also suggest that similarity *reverses* the depletion effect. Exerting self-control in a situation that involves a certain response conflict appears to facilitate self-control in a subsequent situation that involves a highly similar response conflict. Adapting to a response reversal task facilitates performance in a subsequent response reversal task (Study 3).

Inhibiting food intake in a first phase enhances food intake control in a subsequent taste test (Study 4). The implication of these findings is that exerting effort is not a sufficient condition for the ego depletion effect (in the sense of reduced self-control capacity) to occur. People in the high similarity conditions of studies 3 and 4 had exerted self-control in the first phase but performed better in the second phase than control participants. Effort does not necessarily induce depletion.

The most important implication of our data is that the self-control strength model may need revision. In all studies, we used tasks that have been firmly established as depleting tasks in the literature. Moreover, when we used the two-phase paradigm that characterizes the depletion literature, we replicated the depletion effect in the low similarity conditions. Still, the self-control strength model did not well in situations in which the response conflict in the two phases was similar. Although suppressing thoughts and inhibiting responses is depleting, we found that performance improved during the task (Study 1&2). Although people had exerted effort and were depleted (as validated by our finding that self-control performance deteriorated in tasks involving a different response conflict), their self-control performance improved when the response conflict in the two phases was similar (Studies 3 and 4). These findings cannot be accounted for by a muscle metaphor. Muscles get exhausted in using, whether or not they are used in similar or different tasks. The muscle metaphor implies that depletion of the mental resource that the self-control strength model refers to should not depend on the similarity of the subsequent situations. However, our data strongly suggest that it does.

Our data also have implications for the societal scope of ego depletion effects. Baumeister and Heatherton (1996) documented the societal costs of self-control breakdown. The depletion effect was put forward as the culprit behind much of people's misbehaviors as it provides an explanation for why people's capacity to exert self-control is dramatically limited.

The fact that depletion effects set in after a mere five minutes of thought suppression (e.g. Muraven & Slessareva, 2003) only boosted the perceived maliciousness of the ego depletion effect. However, our data suggest a very different possibility: the ego depletion effect may not point at an all too rapid drain of scarce mental resources, thereby impeding people from behaving in an appropriate way. Rather, it may be a side-effect of an adaptive process that helps people to deal with highly demanding situations.

Indeed, cognitive control theory presents people's ability to exert control as a strong asset. According to Botvinick et al. (2001), cognitive control has the flavor of strategic behavior. The shift in cognitive control allows people to predict aspects of future behavior based on current ACC activation. Conflict has the potential to act as an early warning system, allowing people to deal with problems before they actually occur. Miller and Cohen (2001) also observed that the conflict detection system allows people to allocate mental resources in an optimal way. For instance, drivers pay closer attention to the road on a dark and rainy night than on a bright day. Such adjustments are adaptive, in view of the well-recognized capacity limits on cognitive control. Such adjustments would correspond to strength of the PFC activity. In this way, cognitive control theory offers an example of how neurally plausible mechanisms can account for self-control, without recourse to a 'homunculus' (Miller & Cohen, 2001).

Future research opportunities

One of the reasons why the ego depletion effect triggers so much research attention may be its intuitive appeal. People all experience episodes of weak willpower which are often related to tiredness (Muraven et al., 1998). However, this intuition does not necessarily match to the situation in the lab. Indeed, depletion of mental resources may actually exist, but

probably sets in much later than after five minutes of thought suppression or attention regulation. Schellekens, Sijtsma, Vegter, and Meijman (2000) found sustained depletion effects (poorer performance) after a full afternoon of exerting effort in highly demanding tasks. Further, engaging in a Stroop task for 45 minutes has been shown to actually deplete blood sugar levels (Fairclough & Houston, 2004). An interesting line for future research is finding out when blood sugar depletion also starts impeding *similar* self-control tasks.

A related interesting research question pertains to the moderating role of success at adapting to a particular response conflict. Whenever a response is successful, reinforcement signals increase the corresponding pattern of activity by strengthening connections between the PFC neurons that are activated by that response. Because of this strengthened pathway, task-relevant responses may eventually gradually become automatic. When this happens, conflict and hence the need for control diminishes. Activation in the ACC reduces, which is passed on to the PFC, triggering it to adjust the strength of its influence on processing (Botvinick et al., 2001; Miller & Cohen, 2001). Gradually, the PFC becomes irrelevant in the control of a certain task (e.g. riding a bike, Norman & Shallice, 1986).

Consistent with this hypothesized process, the degree of interference from word reading on color naming depends on the frequency of incongruent trials, with less interference occurring when incongruent trials are frequent (e.g., Lindsay & Jacoby 1994; Tzelgov, Henik, & Berger, 1992). Inconsistent with this process, however, Paus, Petrides, Evans, and Meyers (1993) showed that including response reversals in the Stroop tasks required sustained cognitive control. Future research may search for moderating factors that clarify the distinction between tasks that impede complete adaptation (e.g. response reversal tasks) and tasks that allow for complete adaptation (e.g. riding a bike). The answer to this question has implications for the scope of the ego depletion phenomenon. It allows us to predict that depletion effects (in the sense of impaired self-control performance at unrelated tasks) may

occur only when people are still adapting to a response conflict but not after they fully adapted. Specifically, engaging in a demanding task for five minutes may be more ‘depleting’ (in the sense that it impedes self-control performance at unrelated tasks) than engaging in it for half an hour.

Putting the ego depletion effect in a cognitive control context opens up other interesting avenues for future research. Cognitive control reflects a compromise in the trade-off between flexibility and robustness. Robustness is required in the face of distractions, but flexibility is required in the face of novel demands. Positive affect seems to play an important role in determining people’s position on this trade-off. Dreisbach and Goschke (2004) found that positive affect increases the distractibility in tasks that require cognitive control, which suggests that positive affect pushes the system toward greater flexibility at the cost of reduced inertia. Relying on our claim that depletion effects (i.e. reduced self-control performance at unrelated tasks) reflect inertia in the cognitive control system, we submit the prediction that depletion effects will be attenuated with high levels of positive affect. In addition, we predict that individual differences such as perseverance or reactivity (Whiteside & Lynam, 2001) will attenuate or strengthen depletion effects to the extent that they support inertia or flexibility.

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Figure Captions

Figure 1. Time needed to respond to an item as a function of item position.

Figure 2. Interference effect on a response reversal task as a function of the similarity between the response conflict in phase 1 and phase 2.

Figure 3. Self-control performance (standardized) as a function of the similarity between the second task (high for the Taste test and low for the Anagram) and preceding level of food temptation.

Figure 1

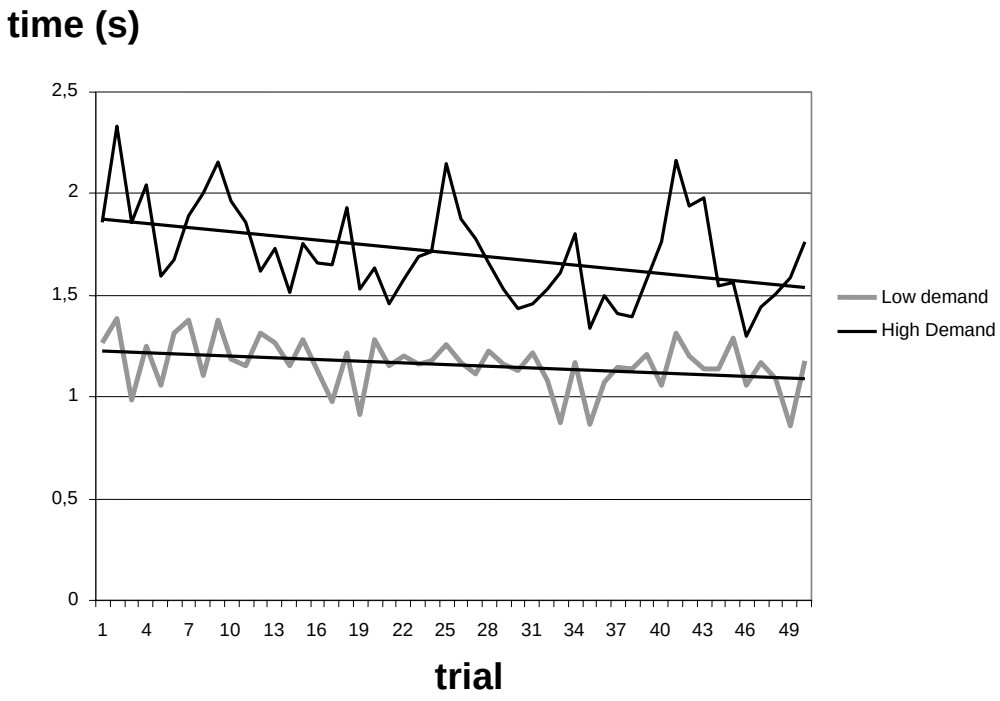

time (s)
2,5
2
1,5
1
0,5
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49
trial
Low demand
High Demand

Figure 2

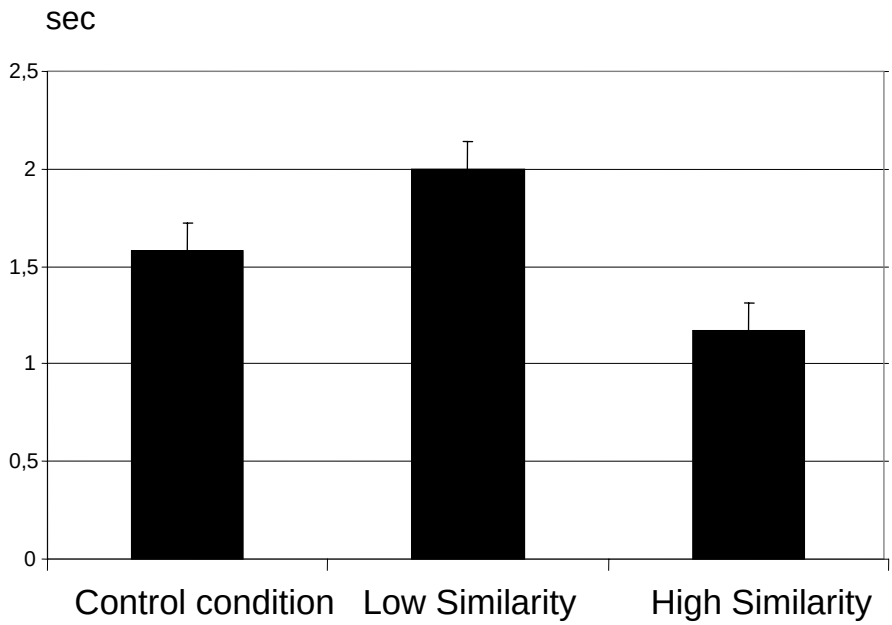
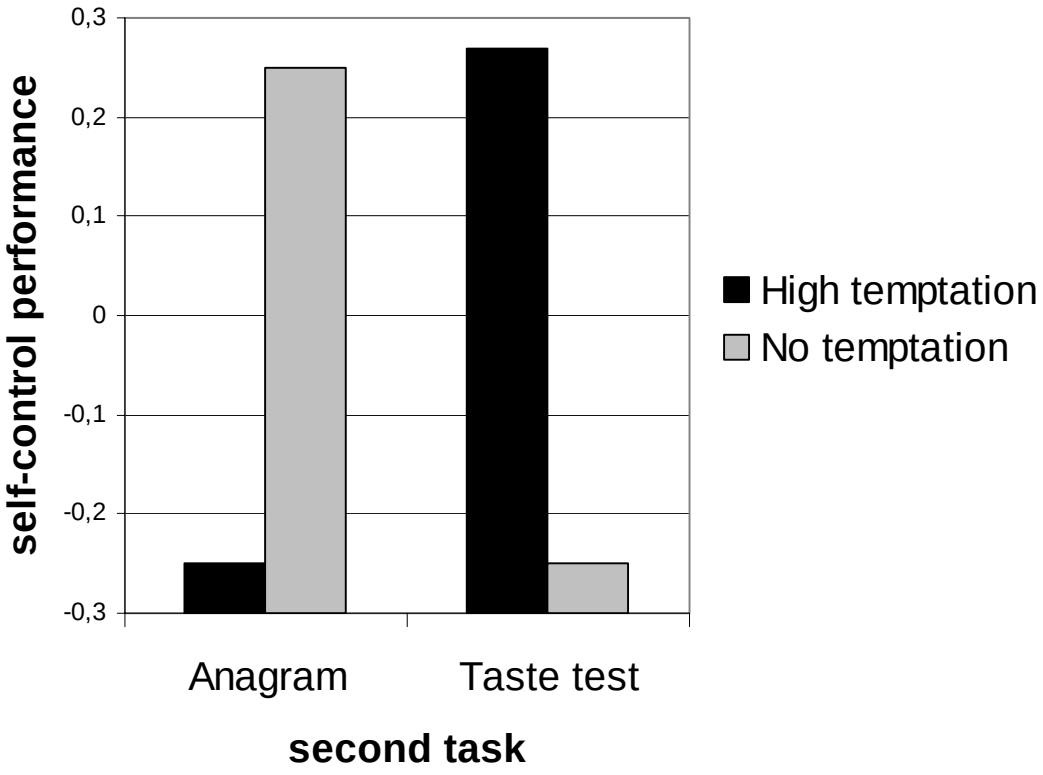

sec
2,5
2
1,5
1
0,5
0
Control condition
Low Similarity
High Similarity

Figure 3


0,3
0,2
0,1
0
-0,1
-0,2
-0,3
self-control performance
High temptation
No temptation
Anagram
Taste test
second task